Modelling Chemical Looping Combustion of natural gas: simulation, validation and optimization

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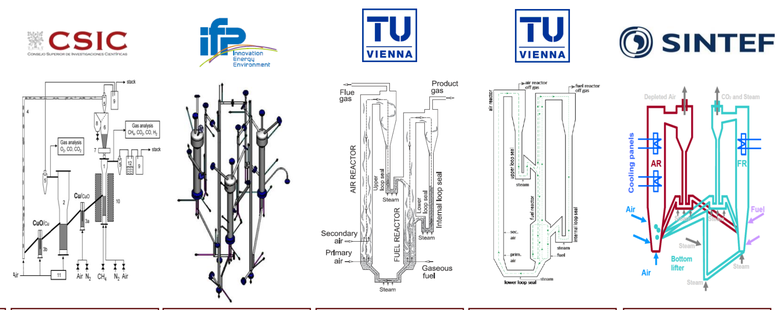
Introduction

CLC with impregnated CuO/Al_2O_3 oxygen carrier (ICB-CSIC)

- Impregnated materials developed by ICB-CSIC show high reactivity with low content of metal oxide (Cu, Fe, Ni, Mn)
- The **Cu-based oxygen carrier impregnated on Al_2O_3** has been tested in CLC units up to 150 kW_{th}
- 5000 h estimated lifetime with comercial Al_2O_3 support
- Cu-based particles prepared by impregnation have shown complete combustion of natural gas, or not, depending on the CLC unit
  - Why? What should be the design or operating conditions for the Cu-based oxygen carrier?

The objective of this work was to determine suitable design parameters and operating conditions for the complete combustion of CH_4 with the impregnated Cu-based oxygen carrier developed by ICB-CSIC

Testing Cu14γAl oxygen carrier in CLC units

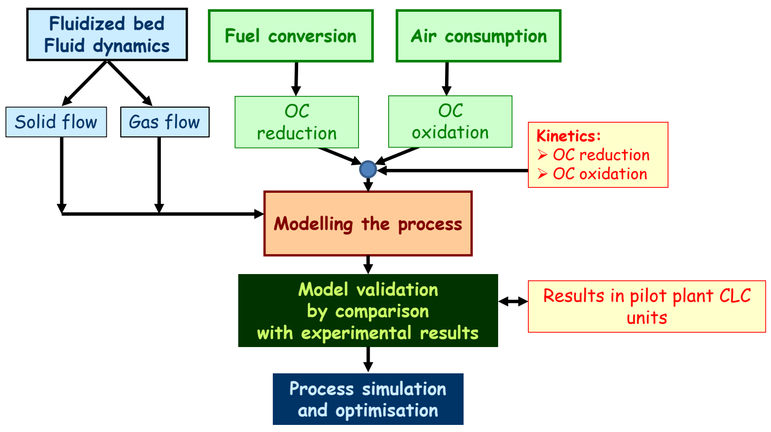


Location	ICB-CSIC	IFP - TOTAL	TUV	TUV	SINTEF
Power (kW_{th})	10	10	120	120	150
Configuration	BFB-BFB	BFB-BFB-BFB	CFB-CFB	CFB-CFB	CFB-CFB
Operat. time (h)	200	160	100	25	n.a.

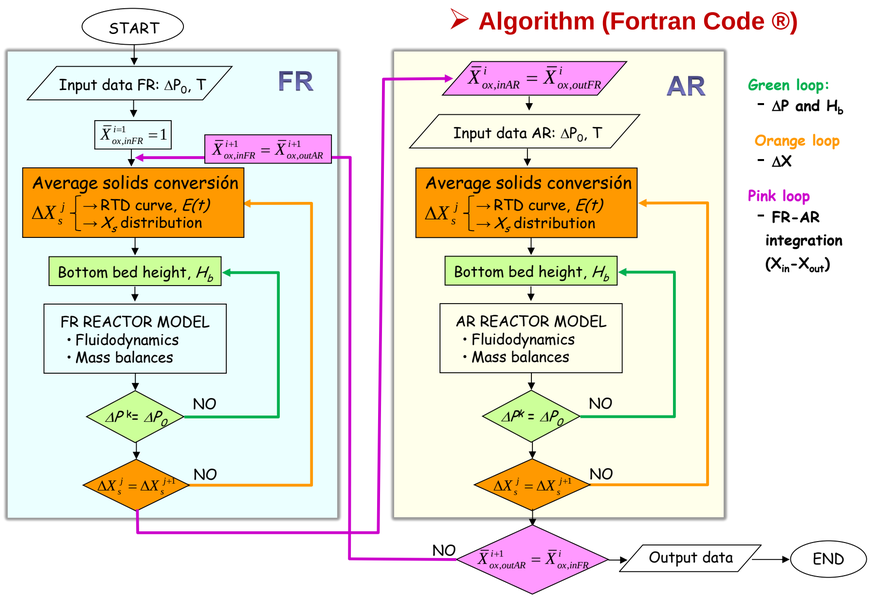
Development & validation of the CLC model: air and fuel reactors

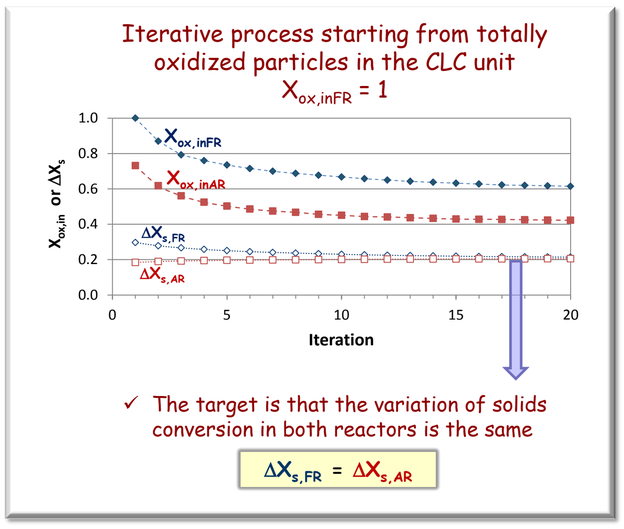
The CLC model: fluid dynamics + mass balances

A mathematical model for a CLC system with interconnected fluidized bed fuel and air reactors was developed

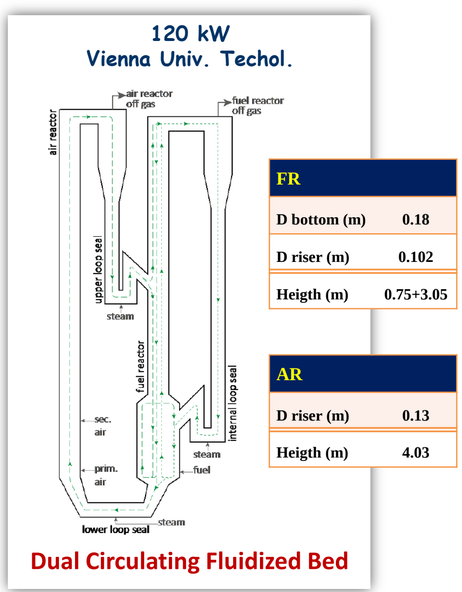


Integration of the fuel and air reactors



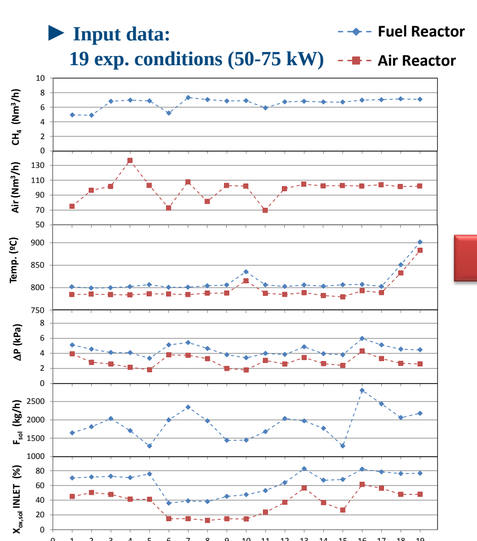


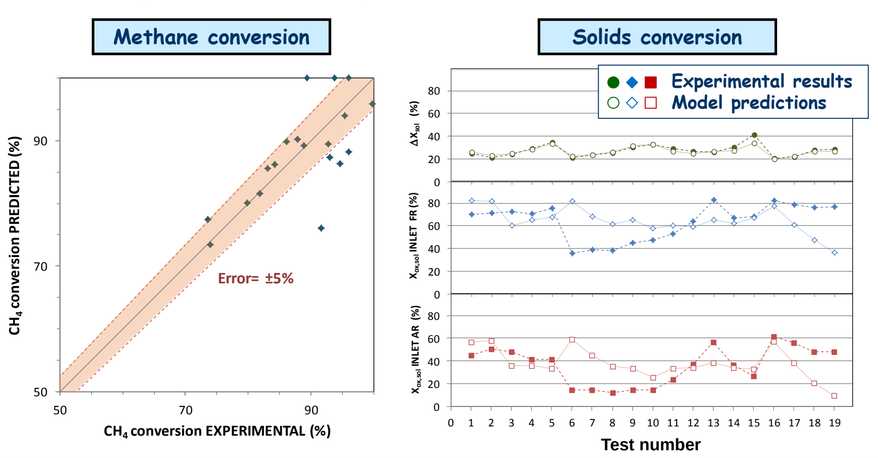
Model validation vs. Experimental results



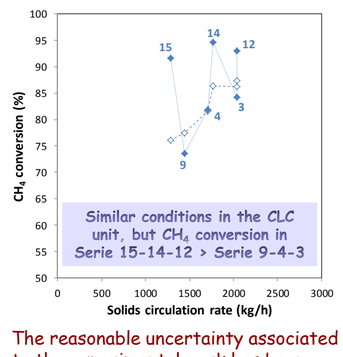
FR	
D bottom (m)	0.18
D riser (m)	0.102
Heigth (m)	0.75+3.05

AR	
D riser (m)	0.13
Heigth (m)	4.03





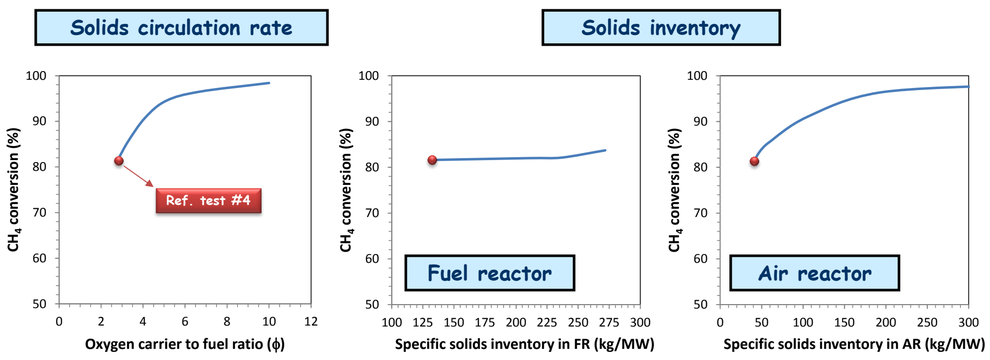
Origin of observed deviations



✓ The reasonable uncertainty associated to the experimental work has been suggested as one of the possible reasons for some observed deviation

Optimization: effect of relevant parameters on methane conversion

Effect of operating conditions



➢ **To improve CH_4 conversion:**

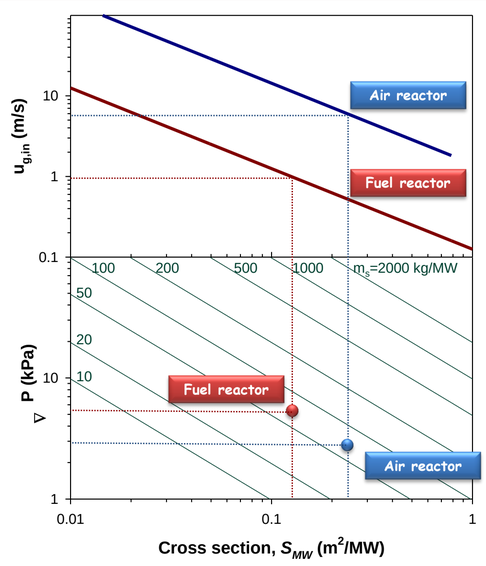
- ❑ The solids inventory in the air reactor and the solids circulation rate has a relevant influence on the methane conversion
- ❑ Adding more solids to the fuel reactor is not an appropriate strategy in order to optimize the amount of solids in the CLC unit to fully convert the fuel

➢ **Test #4** — CH_4 conversion: 81.6 %
- ϕ = 2.8
- Inventory in FR: 132 kg/MW
- Inventory in AR: 41 kg/MW

➢ **Test #4 IMPROVED**
- ϕ = 4
- Inventory in FR: 132 kg/MW
- Inventory in AR: 120 kg/MW

CH_4 conversion: 100 %

Determination of the design parameters



CONCLUSIONS

- ❑ Insufficient oxygen transference rate, mainly in the air reactor, was responsible for low methane conversion at conditions in the CLC unit at TUV
- ❑ The solids circulation rate and the solids inventory in the air reactor were identified as the most relevant parameters in order to achieve complete fuel combustion

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